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LIGA Lithography

LIGA is a German acronym that stands for Lithographie, Galvanoformung and Abformung, and when translated it means lithography, electroplating and molding. LIGA is a three stage micromachining technology used to manufacture high aspect ratio microstructures. Originally LIGA technology was researched in Germany in order to be used for the separation of uranium isotopes. In the 1970s, semiconductor manufacturers believed that optical lithography had reached its resolution limitations. In 1982 the first technical publication of LIGA technology revealed all significant features and properties. LIGA had evolved as a versatile technology, which sparked interest for semiconductor manufacturers.

Initially, semiconductor manufacturers were interested in X-ray LIGA due to its technical capabilities of generating high aspect ratio microstructures with great precision. The method enables manufacturing of microstructures with large structural height with thickness fluctuating from a few hundred micrometers to thousands of micrometers. X-ray LIGA has accomplished the manufacturing of microstructures in a variety of materials ranging from polymers to metals, alloys and ceramics with detailed dimensions and smooth straight sidewalls. IBM exploited synchrotron radiation in order to demonstrate that X-ray LIGA could be used for semiconductor patterning. After Henry Guckel of the University of Wisconsin brought LIGA technology to the USA, his laboratory contributed new ideas and concepts in the 1990s. However, after the industry spent an excess of $1 billion, it started to move away from X-ray LIGA and towards extreme ultraviolet LIGA (EUV) primarily because EUV LIGA was more economical. Although EUV LIGA was economical when compared to X-ray LIGA, the quality of the microstructures was sacrificed.

LIGA is a hybrid fabrication technique combining IC and classical manufacturing technologies. The method borrows lithography from the IC industry and electroplating and molding from classical manufacturing. LIGA not only has the same ability as classical machining to create a wide variety of shapes from different materials, but also is able to create structures with high aspect ratio and reasonably good absolute tolerances. LIGA lithography uses different kinds of light source such laser light, electron or ion beams, or X-rays from a synchrotron radiation source to expose the coated photoresist wafer. However, in this project we mainly focus on the application of x- ray lithography using synchrotron light source because the X-ray lithography is superior to others LIGA lithography process because of the use of a shorter wavelength and a very large DOF (Depth of Focus) and due to the fact that exposure time and development conditions are not fixable.

The main function of the three stage process of LIGA such as lithography, electroplating, and molding are to manufacture of high aspect ratio and 3-D microstructures in a wide variety of materials for instance metals, polymers, ceramics, and glasses. Until now, poly-methyl-methacrylate (PMMA) has almost exclusively been used as the x-ray resist of choice. An X-ray resist should have the following properties; for example, it must have a high sensitivity to x-rays and an appropriate absorptive of x-rays. It has high contrast in the developer (the ratio of dissolution rate in the unexposed and exposed areas should be approximately 1000 to obtain excellent resolution or micro-features). It has good adhesion to the substrate. It can be easily removed after the electroforming step is completed.

In the **Figure 1** shown below, x-ray sensitive resist such as poly -methyl-methacrylate (PMMA) exposed to a collimated source of x-ray radiation. LIGA lithography also uses shadow printing mask alignment. The development of the exposed resist results 3-D replication of patterns, and polymeric structures left standing on a supporting conductive substrate. An electroforming procedure is used to fill in the spaces between the polymeric features with metal plating and to remove the remaining resist. Micro molding uses a mold insert for injection molding or hot embossing. The possibility to replicate hundreds of part with the same insert opens the door to cheap mass production.

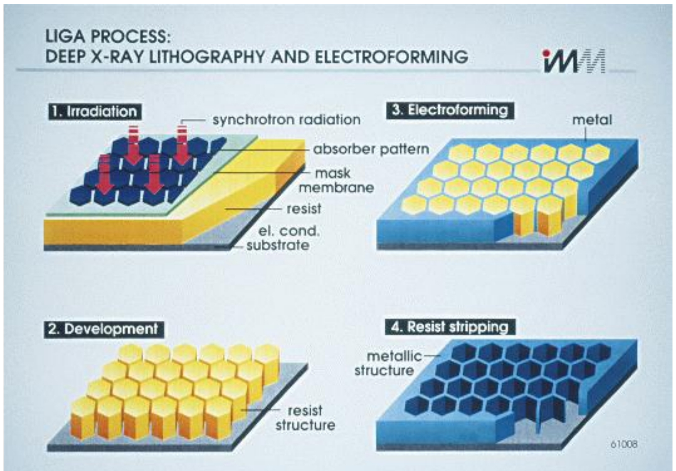

Figure1: Deep x-ray lithographic process

Although LIGA process is distinctive from other lithography process, it has many advantages. X-ray LIGA has impacted microfabrication with the ability to offer technical features such as, spatial resolution, quality, high aspect ratios and sidewall properties superior to any other lithography process. LIGA is considered a flexible technology since it offers the ability to provide microstructures in a large selection of materials although the preferred material is polymer. LIGA can fabricate polymer components with submicron accuracy. While LIGA can be an expensive process when using X-ray LIGA, EUV LIGA can be utilized to fabricate lower aspect ratios microstructures at a more economical rate.

The essential disadvantage to LIGA is high process cost, especially for X-ray LIGA. X-ray LIGA requires the usage of a short wave length x-ray source in order to expose and penetrate the thick (e.g. hundreds of micrometers or even millimeters) PMMA photoresist. Using an x-ray as the main energy source created a gigantic waste of resources when compared to EUV LIGA. Furthermore, transition from research to production becomes arduous due to the LIGA process, which requires an expensive facility with high qualified staff to operate the cleanrooms, expensive equipment, laboratories etc. Not to mention the time and demand of resources required to fabricate high quality components.

Applications for high precision microstructures exist in many fields. LIGA has been widely used to fabricate microstructures for MEMS devices. The automotive and aerospace industry utilizes LIGA to fabricate sensors, actuators, trajectory sensing devices and mass spectrometers. Another application where LIGA components are required is in microoptical components due to the demand of superior and precise performance. Furthermore, any application that dependent structures benefit from high aspect ratios and high precision etc. can benefit from LIGA components.

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